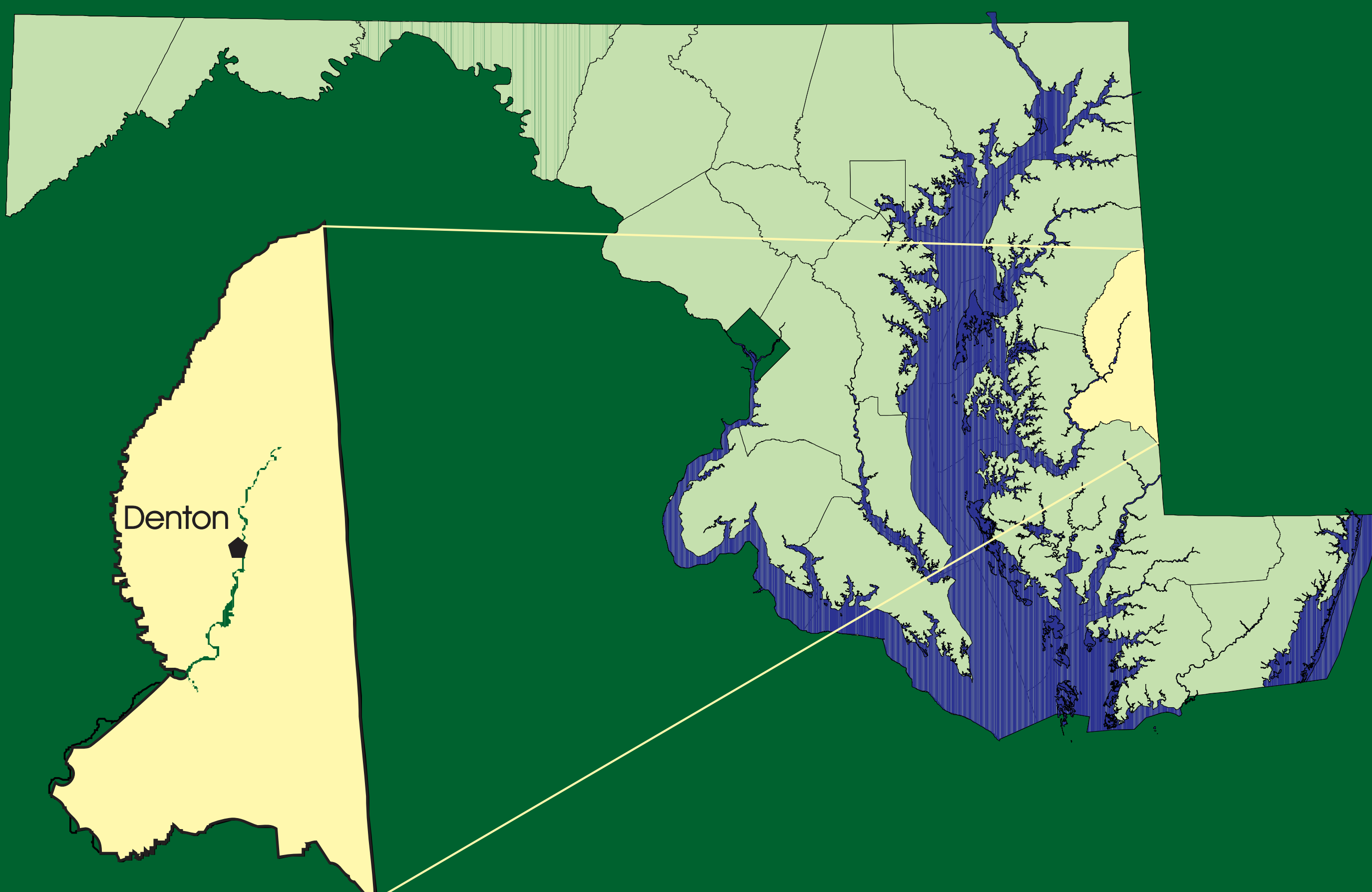
CAROLINE COUNTY

RESULTS OF THE 1994-1997 MARYLAND BIOLOGICAL STREAM SURVEY: COUNTY ASSESSMENTS



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CAROLINE COUNTY

Results of the 1994-1997 Maryland Biological Stream Survey: County-Level Assessments

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December 2001

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FOREWORD

This report is based on results of the Maryland Biological Stream Survey (MBSS), a program funded primarily by the Power Plant Research Program and administered by the Maryland Department of Natural Resources (MDNR). Field data for the MBSS were collected by the Maryland Department of Natural Resources. Analyses of water chemistry samples were conducted by the University of Maryland's Appalachian Laboratory. Much of the initial data analysis was conducted by Versar, Inc. for MDNR's Power Plant Assessment Division.

This report helps fulfill two outcomes in MDNR's Strategic Plan: 1) A Vital and Life Sustaining Chesapeake Bay and Its Tributaries, and 2) Sustainable Populations of Living Resources and Healthy Ecosystems.

ACKNOWLEDGMENTS

The 1994-1997 Maryland Biological Stream Survey has been a cooperative effort among several agencies, consultants and academic institutions. We wish to thank Nancy Roth and Ginny Mercurio from Versar in helping to compile some of the data used in this report. Versar also designed the sampling program, obtained landowners' permissions, and helped manage the data. We are also grateful to the many individuals from Maryland Department of Natural Resources, the University of Maryland's Appalachian Laboratory (AL), and the University of Maryland's Wye Research and Education Center (WREC) who comprised the field crews and did a great job collecting the data. MDNR staff also digitized watersheds and calculated land use data, provided quality assurance, and conducted field crew training. Nancy Roth and her colleagues at Versar developed the fish Index of Biotic Integrity, and Dr. Sam Stribling and his staff at Tetra Tech, Inc. developed the benthic Index of Biotic Integrity. Dr. Ray Morgan of AL and Mr. Lenwood Hall of the WREC supervised additional field crews and developed the Physical Habitat Index, and Dr. Keith Eshleman of AL assisted with analyses of data on acidified streams. Drs. Wayne Starnes and Bob Reynolds of the Smithsonian Institution (reptiles and amphibians), Dr. Rich Raesly of Frostburg State University (fish), Rita Villella of the U.S. Geological Survey Leetown Science Center (mussels), and Michael Naylor of MDNR (aquatic vegetation) provided taxonomic verifications of voucher specimens. The success of the project resulted from the strong efforts of all these groups. Special thanks go to Ron Klauda for his editorial support and Brenda Morgan for her assistance in formatting, editing, and organizing the report.

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INTRODUCTION

This report presents county-level data from the 1994-1997 Maryland Biological Stream Survey (MBSS or the Survey). Previous reports have documented interim results from the 1995 (Roth et al. 1997) and 1996 (Roth et al. 1998a) sample years. In addition, a comprehensive final report was produced to assess the "state of the streams" throughout the state (Roth et al. 1999). All previous MBSS reports have presented information by individual drainage basins. Because there is a recognized need for stream health information at the county level, a series of reports were prepared; this report is part of that series. This introductory section recounts the origin of the Survey and describes its components.

Origin of the MBSS

More than 10 years ago, the Maryland Department of Natural Resources (MDNR) recognized that atmospheric deposition was one of the most important environmental problems resulting from the generation of electric power. To determine the extent of acidification of Maryland streams resulting from acidic deposition, MDNR conducted the Maryland Synoptic Stream Chemistry Survey (MSSCS) in 1987. The MSSCS estimated the number and extent of streams at that time affected by or sensitive to acidification statewide and demonstrated the potential for adverse effects on biota from acidification. However, little direct information was available on the biological responses of Maryland streams to water chemistry conditions. Data that were available could not be used (because of methodological differences and spatial coverage limitations) to compare conditions across regions or watersheds (Tornatore et al. 1992). Neither was it possible to assess the interactions between acidic deposition and other anthropogenic and natural influences (CBRM 1989). For these reasons, in 1993, MDNR created the MBSS to provide comprehensive information on the status of biological resources in Maryland streams and how they are affected by acidic deposition and other cumulative effects of anthropogenic stresses.

Description of the MBSS

The MBSS is intended to help environmental decision-makers protect and restore the natural resources of Maryland. The primary objectives of the MBSS are:

- to assess the current status of biological resources in Maryland's non-tidal streams;
- to quantify the extent to which acidic deposition has affected or may be affecting biological resources in the state;
- to examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams;
- to compile the first statewide inventory of stream biota;
- to establish a benchmark for long-term monitoring of trends in these biological resources; and
- to target future local-scale assessments and mitigation measures needed to restore degraded biological resources.

In creating the Survey, MDNR implemented a probability-based sampling design as a cost-effective way to characterize statewide stream resources. By randomly selecting sites, the Survey can make quantitative inferences about the characteristics of all 9,258 miles of first-to-third-order, non-tidal streams in Maryland (based on stream length on a 1:250,000-scale base map). MDNR recognized that the utility of these estimates depended on accurately measuring appropriate attributes of streams. The Survey focuses on biology for two reasons: (1) organisms themselves have direct societal value and (2) biological communities integrate stresses over time and are a valuable and cost-effective means of assessing ecological integrity (i.e., the capacity of a resource to sustain its inherent potential).

Fish are an important component of stream integrity and one that also contributes to substantial recreational values. For these reasons, fish communities are a primary focus of the Survey. The Survey collects quantitative data for the calculation of population estimates for individual fish species (both game and nongame). These data can also be used to evaluate fish community composition, individual fish health, and the geographic distribution of commercially important, rare, or non-indigenous fish species. Benthic (bottom-dwelling) macroinvertebrates are another essential component of streams and they constitute the second principal focus of the Survey. The Survey uses rapid bioassessment procedures for collecting benthic macroinvertebrates; these semi-quantitative methods permit comparisons of relative abundance and community composition, and have proven to be an effective way of assessing biological integrity in streams (Hilsenhoff 1987, Lenat 1988, Plafkin et al. 1989, Kerans and Karr 1994, Resh 1995). The Survey also records the presence of reptiles and amphibians (herpetofauna), freshwater mussels, and aquatic plants (both submerged aquatic vegetation (SAV) and emergent macrophytes). The Survey has established rigorous protocols (Kazyak 1996) for each of these sampling components, as well as training and auditing procedures to assure that data quality objectives are met.

Although the MBSS sampling design and protocols provide exceptional information for characterizing the stream resources in Maryland, designation of degraded areas and identification of likely stresses requires additional activities. Assessing the condition of biological resources (whether they are degraded or not degraded) requires the development of ecological indicators that permit the comparison of sampled segment results to minimally impacted reference conditions (i.e., the biological community expected in watersheds with little or no human-induced impacts). The Survey has used its growing database of information collected with consistent methods and broad coverage across the state to develop and test indicators of individual biological components (Stribling et al. 1998, Roth et al. 1998b) and physical habitat quality (Hall et al. 1999). Each of these indicators consists of multiple metrics using the general approach developed for the Index of Biotic Integrity (IBI) (Karr et al. 1986, Karr 1991) and the Chesapeake Bay Benthic Restoration Goals (Ranasinghe et al. 1994). The fish and benthic macroinvertebrate IBIs (which combine attributes of both the number and the type of species found) are widely accepted indicators that have been adapted for use in a variety of geographic locations (Miller et al. 1988, Cairns and Pratt 1993, Simon 1999). The Survey is investigating the possibility of developing additional indicators (e.g., amphibians in small streams with few or no fish) and combining components into a composite indicator of biological integrity.

In addition to developing reference-based indicators, the Survey is applying a variety of analytical methods to the question of which stressors are most closely associated with degraded streams. This involves correlational and multivariate analyses of water chemistry, physical habitat, land use, and biological information (e.g., presence of non-native species). The biological information also provides a valuable opportunity for documenting aquatic biodiversity across the state; the distribution and abundance of species previously designated as rare only by anecdotal evidence can be determined, and unique combinations of species at the ecosystem and landscape levels can be identified. Land use and other landscape-scale metrics will play an important role in identifying the relative contributions of different stressors to the cumulative impact on stream resources. Ultimately, the Survey seeks to provide an integrated assessment of the problems facing Maryland streams that will facilitate interdisciplinary solutions for their restoration. The survey also provides resource managers with the locations of relatively undisturbed streams and watersheds that deserve protection.

METHODS

This section presents the specific study design and procedures used to implement the Maryland Biological Stream Survey. The study area of concern and the sampling design developed to characterize it are presented, along with field and laboratory methods for each component: fish, benthic macroinvertebrates, reptiles and amphibians, physical habitat, and water chemistry. Methods for aquatic vegetation and mussel sampling are presented, but the resulting data are not included in this report. A full description of MBSS methods can be found in Kazyak (1996).

MBSS Study Design

The Survey study area comprises 17 distinct drainage basins across the state. Random sampling was used to allow the estimation of unbiased summary statistics (e.g., means, proportions, and their respective variances) for the entire state, a particular basin, and subpopulations of interest (e.g., streams with pH < 5).

Because it would have been cost prohibitive to visit a sufficient number of sites in all basins in a single year, lattice sampling was used to schedule sampling of all basins over a three-year period, 1995-1997. Lattice sampling, also known as multistratification, is a cost-effective means of allocating effort across time in a large geographic area (Heimbuch 1999, Jessen 1978, Cochran 1977). A table, or lattice, was formed by arranging 17 basins in 17 rows, and the years in 3 columns. Lattice sampling was the method used for selecting cells from this 17x3 table so that all basins would be sampled over a three-year period and all basins would have a non-zero probability of being sampled in a given year. The data presented in this report include those collected at random sampling sites within the 17 principal basins in Maryland, as well as sites from the 1994 demonstration project. Because no estimates were calculated for this report, these data were included to supplement the number of sites.

The sampling frame for the Survey was constructed by overlaying basin boundaries on a map of all blue-line stream reaches in the study area as digitized on a U.S. Geological Survey 1:250,000 scale topographic map. This sample frame was similar to that used by the earlier Maryland Synoptic Stream Chemistry Survey (MSSCS) conducted in 1987 (Knapp and Saunders 1987, Knapp et al. 1988). The Strahler convention (Strahler 1957) was used for ranking stream reaches by order; first-order reaches, for example, are the most upstream reaches in the branching stream system. Sampling was restricted to non-tidal, third-order and smaller stream reaches, excluding impoundments that were non-wadable or that substantially altered the riverine nature of the reach (Kazyak 1994). Together, these first-through third-order streams comprise about 90% of all stream and river miles in Maryland. Stream reaches were further divided into non-overlapping, 75-meter segments; these segments were the elementary sampling units from which biological, water chemistry, and physical habitat data were collected.

The 1995-1997 MBSS study design was based on stratified random sampling of segments within each basin; each basin was stratified by stream order. Within a stream order, the number of segments sampled per basin is proportional to the number of stream miles in the basin. To achieve the target number of samples per stream order within each basin, a given number of segments were randomly selected from each basin and ranked in order of selection. In all basins, extra segments were selected as a contingency against loss of sampling sites from restricted access to selected streams or from streams that were dry, too deep, or otherwise unsampleable owing to field conditions. In some basins, where only a small number of sites would have been selected using this method, additional random sites were selected to increase sample size. These extra sites (selected at random using the method described above) were used to provide better basinwide estimates; they were not included in the estimates of statewide conditions.

Permissions were obtained to access privately owned land adjacent to or near each stream segment. The procedures for obtaining permissions are described in Chaillou (1995). Because landowner permissions were obtained in a synoptic fashion and some variation in these rates occurred, we obtained more permissions than were needed for the Survey. Only the highest ranking sites were sampled until the target goal for that basin was reached. For the three year study, the success rate for obtaining permission to access stream sampling segments was high. Eighty-eight percent of sites that were targeted for permission were sampled.

Reasons for permission denial varied and generally reflected the preferences of landowners regarding property access, rather than any specific types of land. In rare cases, permission denial may affect the interpretation of Survey estimates, but only where denials occur in streams with characteristics that differ from the general population of streams. In one example of potential bias, several sites with known coal mining activities in the North Branch Potomac basin denied permission to sample, likely under representing the proportion of acid mine drainage streams in the population.

Field and Laboratory Methods

Benthic macroinvertebrate and water quality sampling were conducted in spring, when the benthos are thought to be reliable indicators of environmental stress (Plafkin et al. 1989) and when acid deposition effects are often the most pronounced. Fish, reptiles and amphibians, aquatic vegetation, and mussel sampling, along with physical habitat evaluations, were conducted during the low-flow period in summer. Fish community composition tends to be stable during summer, and low flow is advantageous for electrofishing. Because low-flow conditions in summer may be a primary factor limiting the abundance and distribution of fish populations, habitat assessments were performed during the summer. The sample size in summer is lower than in spring because some streams were dry in summer or were, in rare cases, otherwise unsampleable.

To reduce temporal variability, sampling during spring and summer was conducted within specific, relatively narrow time intervals, referred to as index periods (Janicki et al. 1993). These index periods were defined by degree-day limits for specific parts of the state. This approach provided a synoptic assessment of the current status of stream biota, water quality, and physical habitat in the 17 basins sampled. The spring index period was the time period between approximately March 1 and May 1, with end of the index period determined by degree-day accumulation as specified in Hilsenhoff (1987). In reality, most spring samples (78%) were collected in March, well before degree-day accumulation limits were approached. The summer index period was between June 1 and September 30 (Kazyak 1994).

Data Collection and Measurement

Field sampling followed procedures specified in the MBSS sampling manual (e.g., Kazyak 1996). A summary of the variables measured and the field and laboratory methods used to conduct the sampling follows.

Fish

Fish were sampled during the summer index period using double-pass electrofishing within 75-meter stream segments. Block nets were placed at each end of the segment and direct current backpack electrofishing units were used to sample the entire segment. An attempt was made to thoroughly fish each segment, and consistent effort was applied over the two passes. This sampling approach allowed calculation of several metrics useful in calculating a biological index and produced unbiased estimates of fish species abundance.

In small streams, a single electrofishing unit was used. In larger streams, two to five units were employed to effectively sample the site. Captured fish were identified to species, counted, weighed, and released. Any individuals that could not be identified to species were retained for laboratory confirmation. For each pass, all individuals of each gamefish species (defined as trout, bass, walleye, pike, chain pickerel, and striped bass) were measured for total length and examined for visible external pathologies or anomalies. For nongame species, up to 100 fish of each species (from both passes) were examined for visible external pathologies or anomalies. For each pass, all non-game species were weighed together for an aggregate biomass measurement; gamefish were also weighed in aggregate to the nearest 10 g.

Electrofishing was also conducted at supplemental, non-randomly selected sites during the summer index period. The presence of each species of fish was recorded for these segments to provide additional qualitative information on statewide fish distributions. Sampling effort at most qualitative sites was based on doubling the elapsed time since the last species was recorded or a minimum of 600 seconds of electrofishing effort.

After processing the fish collected in the field, voucher specimens were retained for each species not previously collected in the drainage basin. In addition, all individuals which could not be positively identified in the field were retained. The remaining fish were released. All voucher specimens and fish retained for positive identification in the laboratory were examined and verified by the MBSS Quality Assurance Officer or ichthyologists at Frostburg State University, Frostburg, Maryland or the Smithsonian Institution, Washington, DC.

Benthic Macroinvertebrates

Benthic macroinvertebrates were collected to provide a qualitative description of the community composition at each sampling site (Kazyak 1996). Sampling was conducted during the spring index period. Benthic community data were collected for the purpose of calculating biological metrics, such as those described in EPA's Rapid Bioassessment Protocols (Plafkin et al. 1989), and use as an indicator of biological integrity for Maryland streams.

At each segment, a 600 micron mesh "D" net was used to collect organisms from habitats likely to support the greatest taxonomic diversity. A riffle area was preferred, but other habitats were also sampled using a variety of techniques including kicking, jabbing, and gently rubbing hard surfaces by hand to dislodge organisms. If available, other habitat types were sampled, including rootwads, woody debris, leaf packs, macrophytes, and undercut banks. Each jab covered one square foot, and a total of approximately 2.0 m^2 (20 square feet) of combined substrates was sampled and preserved in 70% ethanol. In the laboratory, the preserved sample was transferred to a gridded pan and organisms were picked from randomly selected grid cells until the cell that contained the 100th individual (if possible) was completely picked. Some samples had fewer than 100 individuals. The benthic macroinvertebrates were identified to genus, or lowest practicable taxon, in the laboratory.

Index of Biotic Integrity

Sites were evaluated using both the fish (F-IBI) and benthic macroinvertebrate (B-IBI) IBIs developed for the MBSS (for detailed methods, see Roth et al. 1997 and Stribling et al. 1998). IBI scores for the MBSS are determined by comparing the fish or benthic macroinvertebrate assemblages at each site to those found at minimally impacted reference sites. Three separate formulations were employed for the fish IBI, one for each of three distinct geographic areas: Coastal Plain, Eastern Piedmont, and Highland. The two formulations used for the benthic IBI cover the Coastal Plain and non-Coastal Plain regions. Individual metrics for the IBI are scored 1, 3, or 5, based on comparison with the distribution of metric values at reference sites. For either the individual metrics or total IBI, a score of 3 or greater is considered comparable to reference site conditions, while scores falling below this threshold differ significantly from the reference conditions. Scores for the MBSS IBIs are calculated as the mean of the individual metric scores and therefore range from 1 to 5. Some other programs have used a similar approach (e.g., Weisberg et al. 1997), while others have instead computed the IBI as the total of individual metric scores. For example, Karr et al. (1986) calculated IBI as the sum of 12 metric scores, with totals ranging from 12 to 60 points.

Reptiles and Amphibians

At each sample segment, reptiles and amphibians were identified and the presence of observed species was recorded during the summer index period. A search of the riparian area was conducted within 5 meters of the stream on both sides of the 75-meter segment. Any reptiles and amphibians collected during the electrofishing of the stream segment were also included in the species list. Individuals were identified to species when possible. Voucher specimens and individuals not positively identifiable in the field were retained for examination in the laboratory and confirmation by herpetologists at the Smithsonian Institution, Washington, DC, or Towson University, Towson, Maryland.

Physical Habitat

Habitat assessments were conducted at all stream segments as a means of assessing the importance of physical habitat to the biological integrity and fishability of freshwater streams in Maryland. Procedures for habitat assessments (Kazyak 1996) were derived from two currently used methodologies: EPA's Rapid

Bioassessment Protocols (RBPs) (Plafkin et al. 1989), as modified by Barbour and Stribling (1991), and the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI) (Ohio EPA 1987, Rankin 1989). A number of characteristics (instream habitat, epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, riffle/run quality, channel alteration, bank stability, embeddedness, channel flow status, and shading) were assessed qualitatively, based on visual observations within each 75-meter sample segment. Riparian zone vegetation width was estimated to the nearest meter, up to 50 meters from the stream. Additional observations of the surrounding area were used to assign ratings for aesthetic value (based on visible signs of human refuse at a site) and remoteness (based on distance from the nearest road, accessibility, and evidence of human activity). Also recorded were the presence or absence of various stream features including substrate types, various morphological characteristics, beaver ponds, point sources, and stream channelization. Local land uses visible from the stream segment and riparian vegetation type were also noted. Several additional physical characteristics were measured quantitatively to further characterize the habitat for each segment (see Kazyak 1996 for details). Quantitative measurements of the segment included maximum depth, stream gradient, velocity, thalweg depth, number of functional rootwads, number of functional large woody debris, wetted width, sinuosity, and overbank flood height. A velocity/depth profile was measured or other data were collected to enable calculation of discharge.

Physical Habitat Index

The Physical Habitat Index (PHI) was developed using MBSS data from 1994 to 1997 (Hall et al. 1999). As was the case in development of the fish and benthic IBIs, the conceptual approach was based on evaluating the relative importance (discriminatory power) of individual metrics and combinations of metrics explaining natural differences in streams throughout Maryland. These metrics were derived from both quantitative and qualitative habitat data collected during the summer index period. Based on analyses conducted for both fish IBI (Roth et al. 1998) and benthic macroinvertebrate IBI (Stribling et al. 1998) development in Maryland, the State was divided into two regions: the Coastal Plain and non-Coastal Plain. The resulting index was then adjusted to a centile scale that rated each sample segment as follows: Good - 72 to 100; Fair - 42 to 71.9; Poor - 12 to 41.9; and Very Poor - 0 to 11.9.

Water Chemistry

During the spring index period, water samples were collected at each site for analysis of pH, acid neutralizing capacity (ANC), conductivity, sulfate, nitrate-nitrogen, and dissolved organic carbon (DOC). These variables describe basic water quality conditions with an emphasis on factors related to acidic deposition.

Grab samples were collected in one-liter bottles for analysis of all analytes except pH. Water samples for pH were collected with 60 ml syringes, which allowed purging of air bubbles to minimize changes in carbon dioxide content (EPA 1987). Samples were stored on wet ice and shipped on wet ice to the analytical laboratory within 48 hours. Laboratory analyses were carried out by the University of Maryland's Appalachian Laboratory in Frostburg.

Chemical analysis of water samples followed standard methods described in EPA's Handbook of Methods for Acid Deposition Studies (EPA 1987). EPA protocols were followed, except that ANC sample volume was reduced to 40 ml to ease handling. Routine daily quality control (QC) checks included processing duplicate, blank, and calibration samples according to EPA guidelines for each analyte. Field duplicates were taken at 5% of all sites. Routine QC checks helped to identify and correct errors in sampling routines or instrumentation at the earliest possible stage.

During the summer index period, in situ measurements of dissolved oxygen (DO), pH, temperature, and conductivity were collected at each site to further characterize existing water quality conditions that might influence biological communities. Measurements were made at an undisturbed section of the segment, usually in the middle of the stream channel, using electrode probes. Instruments were calibrated daily and calibration logbooks were maintained to document instrument performance.

Recognizing that water temperature is an important factor affecting stream condition, but one that varies daily and seasonally, temperature loggers were deployed at 220 sites in five basins during 1997. The basins sampled were: the Choptank, Susquehanna, Potomac Washington Metro, Patuxent, and Pocomoke. Onset Computer Corporation Optic Stowaway temperature loggers were anchored in each site during the summer index period. Water temperature was recorded every 15 minutes from June 15 until mid-September.

Mussels

During the summer index period, freshwater mussels were sampled qualitatively by examining each 75-meter stream segment for their presence. Mussels were identified to species, their presence recorded, and subsequently released. Species not positively identifiable in the field were retained for confirmation by U.S. Geological Survey (USGS) Biological Resources Division staff.

Aquatic Vegetation

Aquatic vegetation was sampled qualitatively by examining each 75-meter segment for the presence of aquatic plants. Plants were identified to species and their presence recorded for each site. While the primary objective was to document the presence of submerged aquatic vegetation (SAV), emergent and floating aquatic vegetation was also recorded when encountered. Species not positively identifiable in the field were retained for laboratory examination and confirmation by MDNR's staff expert on SAV. Due to the difficulty in long-term preservation, no permanent vouchers of aquatic vegetation were retained.

Data Management

All crews used standardized pre-printed data forms developed for the Survey to ensure that all data for each sampling segment were recorded and standard units of measure were used (Kazyak 1996). Using standard data forms facilitated data entry and minimized transcription error. The field crew leader and a second reviewer checked all data sheets for completeness and legibility before leaving each sampling location. Original data sheets were sent to the Data Management Officer for further review and data entry, while copies were retained by the field crews.

A custom database application, in which the input module was designed to match each of the field data sheets, was used for data entry. Data were independently entered into two databases and compared using a computer program as a quality-control procedure. Differences between the two databases were resolved from original data sheets or through discussions with field crew leaders.

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Maryland Biological Stream Survey Data

COUNTY SUMMARY

A total of 49 sites were sampled in Caroline county by MBSS sampling crews during 1994-1997 (Table 1; Figure 2). In addition, the fish assemblage was characterized on a presence/absence basis at 32 sites to provide a more complete picture of fish species distributions. Appendix A provides a summary of the types of data available for each of the sites sampled.

Species Highlights

A total of 44 fish species were collected in the small to mid-sized streams that were sampled; this number ranks Caroline County eighteenth in the state. Eastern mudminnow, a highly pollution-tolerant species, was found at every site (Table 2). Other common species that were collected include redfin pickerel, tessellated darter, and pirate perch. Other rare fish species in the county included glassy darter (state-listed as endangered), swamp darter, ironcolor shiner, and mud sunfish. The latter three species are currently being considered for listing in Maryland as threatened or endangered. Of special note is a relict population of Blue Ridge sculpin found in a portion of the Nanticoke River basin.

One hundred fifty-five genera of benthic macroinvertebrates were found in the county, putting it in a tie with Allegany county for a ranking of thirteenth in the state. More than one-third of the benthic taxa collected were found at a single site, and some appear to be rare on a statewide basis (Table 3).

Twelve species of reptiles and amphibians were found in or near Caroline county streams (Table 4), ranking the county eighteenth in the state. No state or federally listed species were collected.

Ecological Health

Consistent with the extensive amount of urbanization and agriculture present, the ecological health of Caroline county streams can best be described as Fair to Poor, and conditions generally are worse for benthic macroinvertebrates than for fish (Figures 3 and 4).
The average F-IBI score among sites in Caroline county was 3.66 (rating of Fair, fifth best in Maryland), and the average B-IBI score was 2.3 (rating of Poor, eighth worst in Maryland). Based on F-IBI and B-IBI scores, the highest rated stream in the county is Marshyhope Creek, while the lowest rated streams include Burrsville Branch, an unnamed tributary to Harrington Beaverdam Ditch, and Oldtown Branch (Table 5).

Physical Habitat

Physical habitat in Caroline County was rated as Fair by the Physical Habitat Index. Values ranged from 3.2 to 93.5, with an average score of 51.1 (low end of the Fair range, ranking fourteenth among counties in the state) (Table 6; Figure 5). Other noteworthy points about Caroline County streams include a ranking of twenty-first for large woody debris abundance and a ranking of eighteenth for instream rootwads (trees whose roots protect banks from erosion and provide habitat for aquatic life). However, instream habitat and epifaunal substrate, with an average rating of 12 and 10, respectively, ranked among the best scores in the state.

Nitrate-Nitrogen

Nitrate-nitrogen values at sites sampled in Caroline county averaged 3.61 mg/L, making Caroline the fourth worst county in Maryland. Streams with the lowest nitrate values in the county included Piney Branch and Burrsville Branch, while high nitrate values were observed in Hunting Creek, an unnamed tributary to the Choptank River, Marsh Creek, and an unnamed tributary to Marshyhope Creek (Table 7). In the latter stream, the EPA limit for drinking water (10 mg/L) was exceeded.

Table 1. Site information and land use data collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997. Basin abbreviations are as follows: CK - Choptank River; NW - Nanticoke-Wicomico Rivers.

Site	Latitude	Longitude	Stream Name	Basin	Order	Catchment Acres	% Urban	% Agric.	% Forest
CN-N-002-1-94	39.0909	75.7524	Tidy Island Cr	CK	3	18482.70	2.87	50.36	30.21
CN-N-002-2-94	39.0861	75.7556	Tidy Island Cr	CK	3	19130.80	2.80	50.68	30.05
CN-N-004-311-97	39.0840	75.7550	Tidy Island Cr	CK	3	21137.16	2.73	49.92	30.74
CN-N-005-103-97	38.9300	75.8420	Un Trib To Choptank R	CK	1	2814.31	9.80	59.87	24.82
CN-N-007-3-94	38.8961	75.7420	Webber Br	CK	1	884.10	0.11	77.04	13.27
CN-N-016-107-97	39.0780	75.7920	Un Trib To Tidy Island Cr	CK	1	182.06	0.00	61.01	19.78
CN-N-020-109-96	38.9760	75.8410	Un Trib To Forge Br	CK	1	1684.54	0.71	59.45	25.62
CN-N-023-3-94	38.8915	75.7398	Burrsville Br	CK	1	607.70	9.20	67.64	13.73
CN-N-023-9-94	38.8911	75.7432	Burrsville Br	CK	1	670.40	8.34	67.04	14.75
CN-N-024-113-96	38.7220	75.9600	Un Str	CK	1	537.58	0.19	34.14	38.95
CN-N-028-1-94	38.9607	75.9124	Piney Br	CK	1	1868.60	1.86	76.54	17.34
CN-N-028-2-94	38.9655	75.8857	Piney Br	CK	1	564.30	0.48	74.43	23.88
CN-N-031-122-95	38.7971	75.7506	Tommy Wright Branch	NW	1	2046.19	0.08	62.19	22.46
CN-N-034-1-94	38.7128	75.9369	Marsh Cr	CK	1	2555.20	1.33	70.80	23.48
CN-N-034-2-94	38.7293	75.9224	Marsh Cr	CK	1	418.20	0.41	66.41	30.49
CN-N-035-1-94	38.9103	75.8610	Choptank R	CK	1	758.00	0.17	72.02	14.33
CN-N-035-2-94	38.9103	75.8592	Choptank R	CK	1	830.10	0.21	67.55	18.75
CN-N-039-108-96	39.1290	75.7770	Un Trib To Beaverdam Ditch	CK	1	372.22	0.09	48.53	34.98
CN-N-039-1-94	39.1304	75.7677	Harrington Beaverdam Ditch	CK	1	527.60	0.06	61.99	25.32
CN-N-039-2-94	39.1300	75.7661	Harrington Beaverdam Ditch	CK	1	576.60	1.30	63.38	23.22
CN-N-039-8-94	39.1268	75.7545	Harrington Beaverdam Ditch	CK	1	1278.30	1.23	60.86	23.11
CN-N-041-205-96	38.9810	75.7370	Gravelly Br	CK	2	6439.75	0.03	61.74	26.16
CN-N-043-102-97	38.8500	75.7890	Un Trib To Herring Run	CK	1	2959.67	0.23	60.46	25.72
CN-N-044-1-94	38.8633	75.8062	Watts Cr	CK	2	8355.30	1.43	58.78	23.94
CN-N-044-207-97	38.8850	75.7560	Burrsville Br	CK	2	2382.07	2.39	61.82	22.70
CN-N-044-3-94	38.8776	75.7855	Watts Cr	CK	2	5460.50	1.10	56.40	25.52
CN-N-046-105-97	39.0400	75.8030	Oldtown Br	CK	1	879.03	0.12	43.12	26.80
CN-N-049-116-97	38.8070	75.8570	Robbins Br	CK	1	2770.93	0.60	56.66	30.11
CN-N-050-102-96	39.0910	75.7650	Coolspring Br	CK	1	1052.03	2.21	41.03	39.51
CN-N-050-1-94	39.0894	75.7621	Coolspring Br	CK	1	1302.40	3.04	34.74	44.87
CN-N-050-2-94	39.0994	75.7831	Coolspring Br	CK	1	263.00	2.48	33.63	47.67
CN-N-051-202-96	38.9920	75.7750	Gravelly Br	CK	2	10849.62	0.02	66.23	22.95
CN-N-058-120-97	38.7560	75.9540	Mitchell Run	CK	1	463.40	6.47	53.49	28.95
CN-S-002-111-96	38.7110	75.8870	Hunting Cr	CK	1	4390.14	0.77	76.34	13.42
CN-S-006-208-95	38.7118	75.7842	Ut Marshy Hope Creek	NW	2	5655.28	0.48	71.61	13.20
CN-S-010-117-97	38.6990	75.8980	Hunting Cr	CK	1	6254.24	1.82	77.62	12.11
QA-N-052-202-97	39.0700	75.8510	Mason Br	CK	2	10829.34	0.20	55.04	24.40
QA-N-085-307-97	39.0180	75.8950	Mason Br	CK	3	28211.52	0.50	57.48	23.18
QA-N-085-312-97	39.0150	75.8970	Mason Br	CK	3	28328.19	0.50	57.51	23.11
QA-N-098-301-96	39.0520	75.8730	Mason Br	CK	3	21790.43	0.52	57.83	23.26
QA-N-098-302-96	39.0500	75.8740	Mason Br	CK	3	21793.49	0.52	57.78	23.21
QA-N-098-302-97	39.0410	75.8770	Mason Br	CK	3	22348.39	0.51	57.84	22.98
QA-N-098-307-96	39.0420	75.8770	Mason Br	CK	3	22198.38	0.51	57.92	22.94
QA-N-098-308-96	39.0300	75.8830	Mason Br	CK	3	24340.20	0.52	57.13	23.01
QA-N-098-308-97	39.0340	75.8820	Mason Br	CK	3	23533.13	0.51	57.89	22.86
QA-N-098-309-96	39.0360	75.8800	Mason Br	CK	3	23271.84	0.49	57.74	22.89
QA-N-098-315-97	39.0439	75.8769	Mason Br	CK	3	22297.38	0.51	57.87	23.02
QA-N-105-1-94	39.1020	75.8388	Long Marsh Ditch	CK	2	5190.60	0.24	60.30	23.54
QA-N-105-2-94	39.1002	75.8399	Long Marsh Ditch	CK	2	5210.40	0.24	60.45	23.45

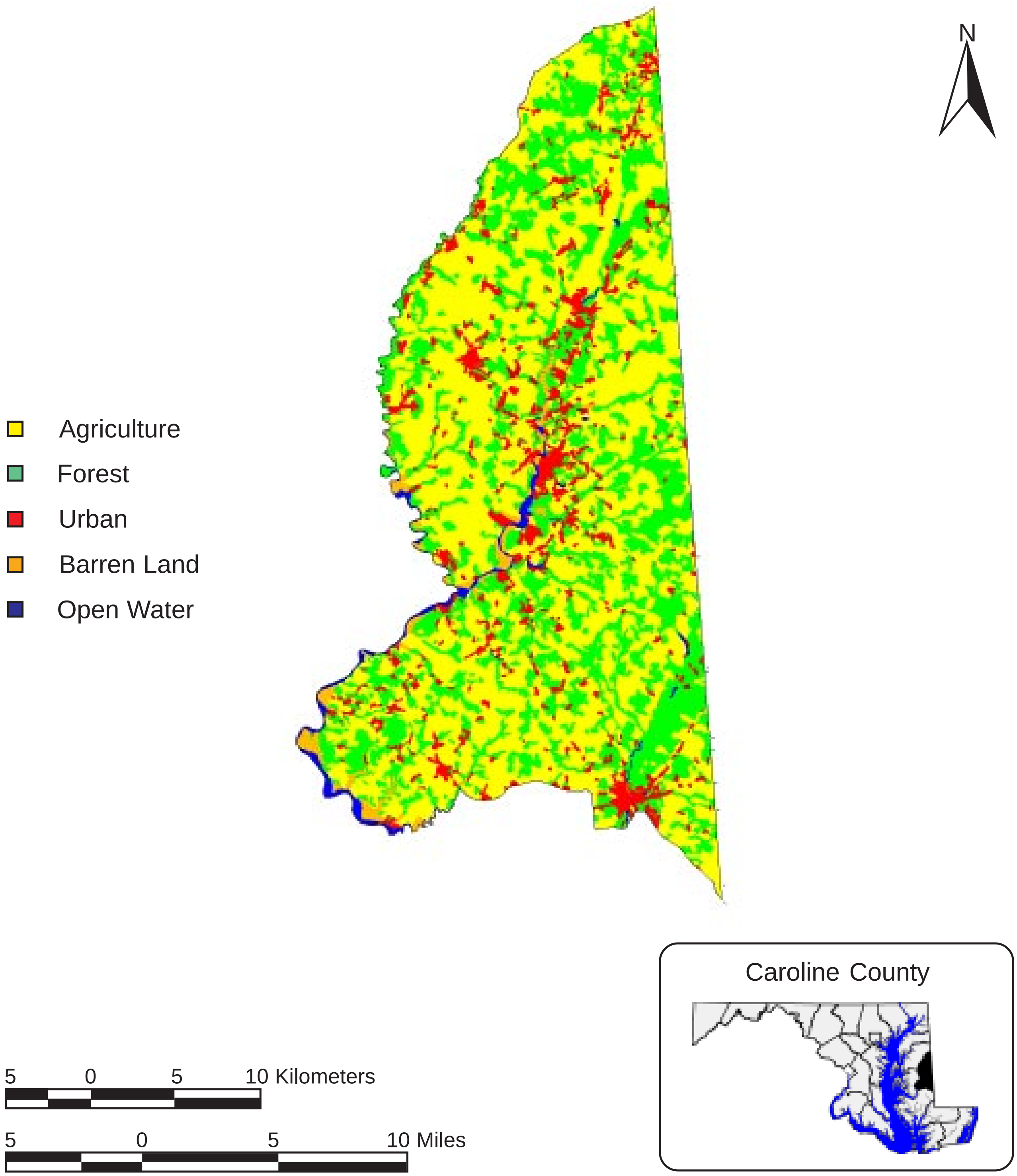

Figure 1. Land use in Caroline County (MOP 1994).

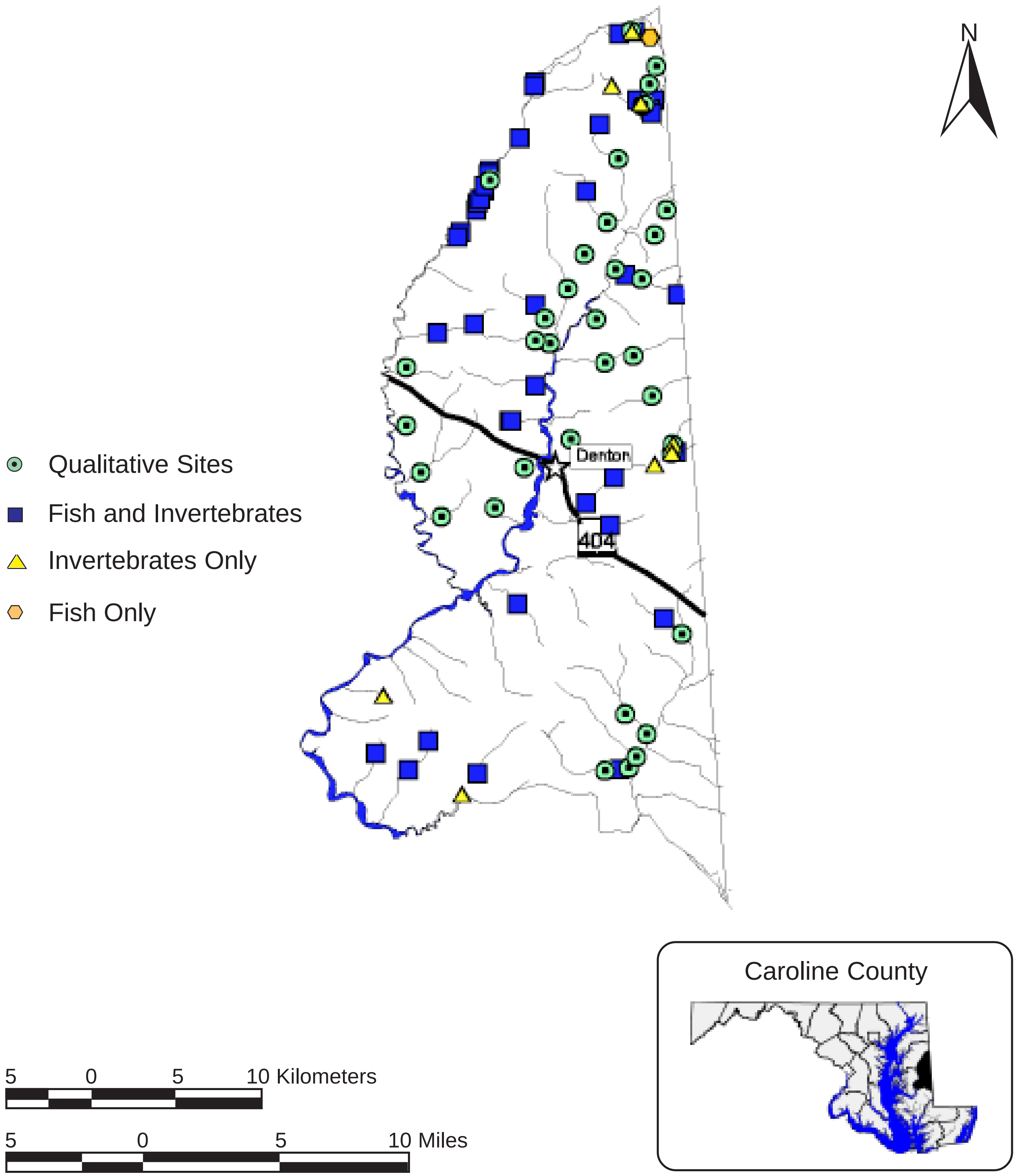

Figure 2. Location of Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Table 2. Percent occurrence of fish species collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Family	Common Name	Scientific Name	Number of Occurrences	Percent Occurrence
Petromyzontidae	least brook lamprey	*Lampetra aepyptera*	16	39.02
Anguillidae	American eel	*Anguilla rostrata*	30	73.17
Cyprinidae	rosyside dace	*Clinostomus funduloides*	7	17.07
	satinfin shiner	*Cyprinella analostana*	2	4.88
	golden shiner	*Notemigonus crysoleucas*	20	48.78
	ironcolor shiner	*Notropis chalybaeus*	5	12.20
	spottail shiner	*Notropis hudsonius*	1	2.44
	swallowtail shiner	*Notropis procne*	15	36.59
	fallfish	*Semotilus corporalis*	15	36.59
Catostomidae	white sucker	*Catostomus commersoni*	1	2.44
	creek chubsucker	*Erimyzon oblongus*	32	78.05
Ictaluridae	yellow bullhead	*Ameiurus natalis*	11	26.83
	brown bullhead	*Ameiurus nebulosus*	14	34.15
	tadpole madtom	*Noturus gyrinus*	25	60.98
	margined madtom	*Noturus insignis*	17	41.46
Esocidae	redfin pickerel	*Esox americanus vermiculatus*	34	82.93
	chain pickerel	*Esox niger*	22	53.66
Umbridae	eastern mudminnow	*Umbra pygmaea*	41	100.00
Aphredoderidae	pirate perch	*Aphredoderus sayanus*	34	82.93
Cottidae	mottled sculpin	*Cottus bairdi*	1	2.44
Percichthyidae	white perch [1]	*Morone americana*		
Centrarchidae	mud sunfish	*Acantharchus pomotis*	7	17.07
	bluespotted sunfish	*Enneacanthus gloriosus*	22	53.66
	redbreast sunfish	*Lepomis auritus*	26	63.41
	pumpkinseed	*Lepomis gibbosus*	31	75.61
	bluegill	*Lepomis machrochirus*	31	75.61
	largemouth bass	*Micropterus salmoides*	20	48.78
	black crappie	*Pomoxis nigromaculatus*	1	2.44
Percidae	swamp darter	*Etheostoma fusiforme*	6	14.63
	tessellated darter	*Etheostoma olmstedi*	33	80.49
	glassy darter [1]	*Etheostoma vitreum*		
	yellow perch	*Perca flavescens*	4	9.76
	shield darter	*Percina peltata*	13	31.71

[1] Qualitative Sites

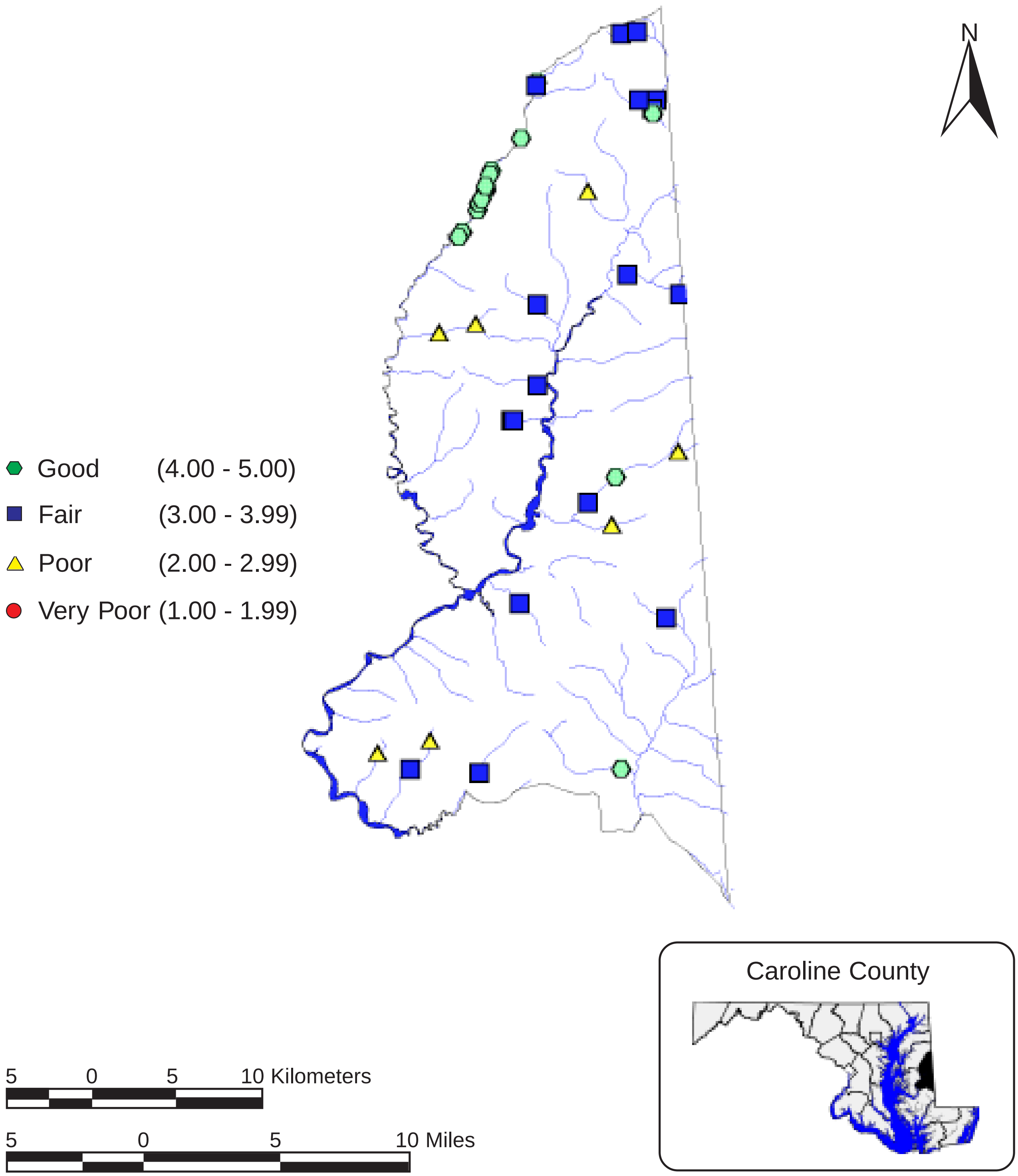

Figure 3. Stream ecological conditions based on the Fish Index of Biotic Integrity (F-IBI) at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Table 3. Tolerance Value (TV)[1], Functional Feeding Group (FFG), Habit, and Percent Occurrence of benthic macroinvertebrate taxa collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997. Abbreviations of habits are as follows: bu - burrower, cn - clinger, cb - climber, sp - sprawler, dv - diver, and sk - skater.

Class	Order	Family	Genus	TV	FFG	Habit	Percent Occurrence
Enopla	Hoplonemertea	Tetrastemmatidae	*Prostoma* Sp.		Predator		11.43
Turbellaria	Tricladida	Planariidae	*Dugesia* Sp.	7	Predator	sp	11.43
Oligochaeta				10	Collector	bu	5.71
Oligochaeta	Lumbriculida	Lumbriculidae		10	Collector	bu	22.86
Oligochaeta	Tubificida	Enchytraeidae		10	Collector	bu	5.71
		Naididae		10	Collector	bu	14.29
		Tubificidae		10	Collector	cn	20.00
Hirudinea				8	Predator	sp	2.86
Gastropoda	Basommatophora	Ancylidae	*Fissia* Sp.	7	Scraper	cb	2.86
		Lymnaeidae	*Pseudosuccinea* Sp.	6	Collector	cb	11.43
		Physidae	*Physella* Sp.	8	Scraper	cb	20.00
		Planorbidae	*Gyraulus* Sp.	8	Scraper	cb	5.71
			Helisoma Sp.	6	Scraper	cb	2.86
			Menetus Sp.	8	Scraper	cb	8.57
			Planorbella Sp.	7	Scraper	cb	2.86
Gastropoda	Mesogastropoda	Hydrobiidae	*Amnicola* Sp.	8	Scraper	cb	14.29
			Hydrobia Sp.		Scraper	cb	2.86
		Pleuroceridae	*Goniobasis* Sp.		Scraper	cb	11.43
		Viviparidae	*Campeloma* Sp.	6	Scraper	cb	2.86
			Viviparus Sp.	1	Scraper	cb	2.86
Pelecypoda	Veneroida	Sphaeriidae	*Pisidium* Sp.	8	Filterer	bu	45.71
			Sphaerium Sp.	8	Filterer	bu	31.43
Copepoda				8	Collector		2.86
Malacostraca	Amphipoda					sp	8.57
		Crangonyctidae	*Crangonyx* Sp.	4	Collector	sp	40.00
		Gammaridae	*Gammarus* Sp.	6	Shredder	sp	37.14
Malacostraca	Decapoda	Cambaridae		6	Shredder	sp	2.86
Malacostraca	Isopoda	Asellidae	*Caecidotea* Sp.	8	Collector	sp	20.00
Insecta	Collembola						2.86
Insecta	Ephemeroptera				Collector		2.86
		Baetidae			Collector	sw, cn	11.43
			Acentrella Sp.	4	Collector	sw, cn	2.86
			Acerpenna Sp.	4	Collector	sw, cn	17.14
			Baetis Sp.	6	Collector	sw, cb, cn	2.86
		Caenidae	*Caenis* Sp.	7	Collector	sp	5.71
		Ephemerellidae	*Ephemerella* Sp.	2	Collector	cn, sw	25.71
			Eurylophella Sp.	4	Scraper	cn, sp	20.00
			Satella Sp.	2	Collector	cn	5.71
		Heptageniidae	*Stenonema* Sp.	4	Scraper	cn	25.71
		Leptophlebiidae			Collector	sw, cn	2.86
			Leptophlebia Sp.	4	Collector	sw, cn, sp	2.86
			Paraleptophlebia Sp.	2	Collector	sw, cn, sp	5.71
		Siphlonuridae	*Siphlonurus* Sp.	7	Collector	sw, cb	2.86
Insecta	Odonata	Aeshnidae	*Basiaeschna* Sp.	6	Predator	cb, sp, cn	2.86
			Boyeria Sp.	2	Predator	cb, sp	5.71
		Calopterygidae	*Calopteryx* Sp.	6	Predator	cb	25.71
		Coenagrionidae			Predator	cb	8.57

Table 3 (cont.). Tolerance Value (TV)[1], Functional Feeding Group (FFG), Habit, and Percent Occurrence of benthic macroinvertebrate taxa collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997. Abbreviations of habits are as follows: bu - burrower, cn - clinger, cb - climber, sp - sprawler, dv - diver, and sk - skater.

Class	Order	Family	Genus	TV	FFG	Habit	Percent Occurrence
			Argia Sp.	8	Predator	cn, cb, sp	5.71
			Enallagma Sp.	8	Predator	cb	2.86
		Cordulegastridae	*Cordulegaster* Sp.	3	Predator	bu	5.71
		Gomphidae	*Gomphus* Sp.	5	Predator	bu	11.43
			Hagenius Sp.	1	Predator	sp	2.86
			Lanthus Sp.	6	Predator	bu	2.86
			Progomphus Sp.	5	Predator	bu	5.71
		Libellulidae		9	Predator		5.71
Insecta	Plecoptera	Nemouridae			Shredder	sp, cn	2.86
			Amphinemura Sp.	3	Shredder	sp, cn	8.57
			Ostrocerca Sp.		Shredder	sp, cn	8.57
			Prostoia Sp.		Shredder	sp, cn	20.00
		Perlidae			Predator	cn	2.86
		Perlodidae	*Clioperla* Sp.	1	Predator	cn	8.57
			Isoperla Sp.	2	Predator	cn, sp	11.43
		Taeniopterygidae	*Oemopteryx* Sp.		Shredder	sp, cn	2.86
			Strophopteryx Sp.		Shredder	sp, cn	17.14
			Taeniopteryx Sp.	2	Shredder	sp, cn	5.71
Insecta	Hemiptera	Corixidae			Predator	sw	5.71
Insecta	Megaloptera	Corydalidae	*Nigronia* Sp.	0	Predator	cn, cb	8.57
		Sialidae	*Sialis* Sp.	4	Predator	bu, cb, cn	2.86
Insecta	Trichoptera	Brachycentridae	*Micrasema* Sp.	2	Shredder	cn, sp	5.71
		Hydropsychidae	*Cheumatopsyche* Sp.	5	Filterer	cn	40.00
			Diplectrona Sp.	2	Filterer	cn	5.71
			Hydropsyche Sp.	6	Filterer	cn	14.29
		Hydroptilidae	*Oxyethira* Sp.	3	Collector	cb	2.86
		Leptoceridae		4	Collector		2.86
			Oecetis Sp.	8	Predator	cn, sp, cb	2.86
			Triaenodes Sp.	6	Shredder	sw, cb	11.43
		Limnephilidae			Shredder	cb, sp, cn	5.71
			Ironoquia Sp.	3	Shredder	sp	5.71
			Limnephilus Sp.	3	Shredder	cb, sp, cn	2.86
			Platycentropus Sp.	4	Shredder	cb	8.57
			Pycnopsyche Sp.	4	Shredder	sp, cb, cn	8.57
		Philopotamidae	*Chimarra* Sp.	4	Filterer	cn	2.86
			Wormaldia Sp.		Filterer	cn	5.71
		Phryganeidae	*Ptilostomis* Sp.	5	Shredder	cb	2.86
		Polycentropodidae	*Polycentropus* Sp.	5	Filterer	cn	11.43
		Psychomyiidae	*Lype* Sp.	2	Scraper	cn	5.71
		Rhyacophilidae	*Rhyacophila* Sp.	1	Predator	cn	2.86
		Uenoidae				cn	2.86
			Neophylax Sp.	3	Scraper	cn	17.14
Insecta	Lepidoptera	Pyralidae			Shredder	cb	2.86
Insecta	Coleoptera	Dryopidae	*Helichus* Sp.	5	Scraper	cn	2.86
		Dytiscidae	*Hydroporus* Sp.	5	Predator	sw, cb	2.86
		Elmidae	*Ancyronyx* Sp.	2	Scraper	cn, sp	5.71
			Dubiraphia Sp.	6	Scraper	cn, cb	28.57

Table 3 (cont.). Tolerance Value (TV)[1], Functional Feeding Group (FFG), Habit, and Percent Occurrence of benthic macroinvertebrate taxa collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997. Abbreviations of habits are as follows: bu - burrower, cn - clinger, cb - climber, sp - sprawler, dv - diver, and sk - skater.

Class	Order	Family	Genus	TV	FFG	Habit	Percent Occurrence
			Optioservus Sp.	4	Scraper	cn	8.57
			Oulimnius Sp.	2	Scraper	cn	2.86
			Stenelmis Sp.	6	Scraper	cn	22.86
		Gyrinidae	*Dineutus* Sp.	4	Predator	sw, dv	5.71
		Haliplidae	*Haliplus* Sp.	5	Shredder	cb	5.71
			Peltodytes Sp.	5	Shredder	cb, cn	5.71
Insecta	Diptera	Ceratopogonidae			Predator	sp, bu	8.57
			Bezzia Sp.	6	Predator	bu	2.86
			Helius Sp.	4	Predator	sp, bu	8.57
		Chironomidae	*Ablabesmyia* Sp.	8	Predator	sp	5.71
			Apsectrotanypus Sp.	5	Predator	bu, sp	2.86
			Brillia Sp.	5	Shredder	bu, sp	2.86
			Chironomus Sp.	10	Collector	bu	5.71
			Clinotanypus Sp.	8	Predator	bu	20.00
			Conchapelopia Sp.	6	Predator	sp	40.00
			Corynoneura Sp.	7	Collector	sp	8.57
			Cricotopus Sp.	7	Shredder	cn, bu	34.29
			Cricotopus/ Orthocladius Sp.		Shredder		54.29
			Cryptochironomus Sp.	8	Predator	sp, bu	5.71
			Diamesa Sp.	5	Collector	sp	2.86
			Dicrotendipes Sp.	10	Collector	bu	22.86
			Diplocladius Sp.	7	Collector	sp	2.86
			Eukiefferiella Sp.	8	Collector	sp	5.71
			Kiefferulus Sp.	10	Collector	bu	2.86
			Labrundinia Sp.	7	Predator	sp	8.57
			Larsia Sp.	6	Predator	sp	2.86
			Micropsectra Sp.	7	Collector	cb, sp	2.86
			Microtendipes Sp.	6	Filterer	cn	22.86
			Nanocladius Sp.	3	Collector	sp	8.57
			Nilotanypus Sp.	6	Predator	sp	2.86
			Omisus Sp.				2.86
			Orthocladiinae A Sp.		Collector		2.86
			Orthocladius Sp.	6	Collector	sp, bu	25.71
			Paramerina Sp.	4	Predator	sp	5.71
			Parametriocnemus Sp.	5	Collector	sp	14.29
			Paratanytarsus Sp.	6	Collector	sp	20.00
			Paratendipes Sp.	8	Collector	bu	2.86
			Phaenopsectra Sp.	7	Collector	cn	2.86
			Polypedilum Sp.	6	Shredder	cb, cn	20.00
			Potthastia Sp.	2	Collector	sp	2.86
			Procladius Sp.	9	Predator	sp	17.14
			Psectrocladius Sp.	8	Shredder	sp, bu	2.86
			Rheocricotopus Sp.	6	Collector	sp	22.86
			Rheotanytarsus Sp.	6	Filterer	cn	17.14
			Stictochironomus Sp.	9	Collector	bu	2.86
			Symposiocladius Sp.		Predator	sp	8.57

Table 3 (cont.). Tolerance Value (TV)[1], Functional Feeding Group (FFG), Habit, and Percent Occurrence of benthic macroinvertebrate taxa collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997. Abbreviations of habits are as follows: bu - burrower, cn - clinger, cb - climber, sp - sprawler, dv - diver, and sk - skater.

Class	Order	Family	Genus	TV	FFG	Habit	Percent Occurrence
			Tanypus Sp.	10	Predator		5.71
			Tanytarsus Sp.	6	Filterer	cb, cn	25.71
			Thienemanniella Sp.	6	Collector	sp	5.71
			Thienemannimyia Sp.		Predator	sp	14.29
			Trissopelopia Sp.		Predator	sp	2.86
			Tvetenia Sp.	5	Collector	sp	5.71
			Zavrelimyia Sp.	8	Predator	sp	2.86
		Empididae	*Chelifera* Sp.		Predator	sp, bu	2.86
			Hemerodromia Sp.	6	Predator	sp, bu	8.57
		Simuliidae	*Prosimulium* Sp.	7	Filterer	cn	54.29
			Simulium Sp.	7	Filterer	cn	34.29
			Stegopterna Sp.	7	Filterer	cn	40.00
		Tipulidae	*Dicranota* Sp.	4	Predator	sp, bu	5.71
			Pseudolimnophila Sp.	2	Predator	bu	2.86
			Tipula Sp.	4	Shredder	bu	8.57

[1] Tolerance values are on a 0 (extremely sensitive) to 10 (tolerant) scale.

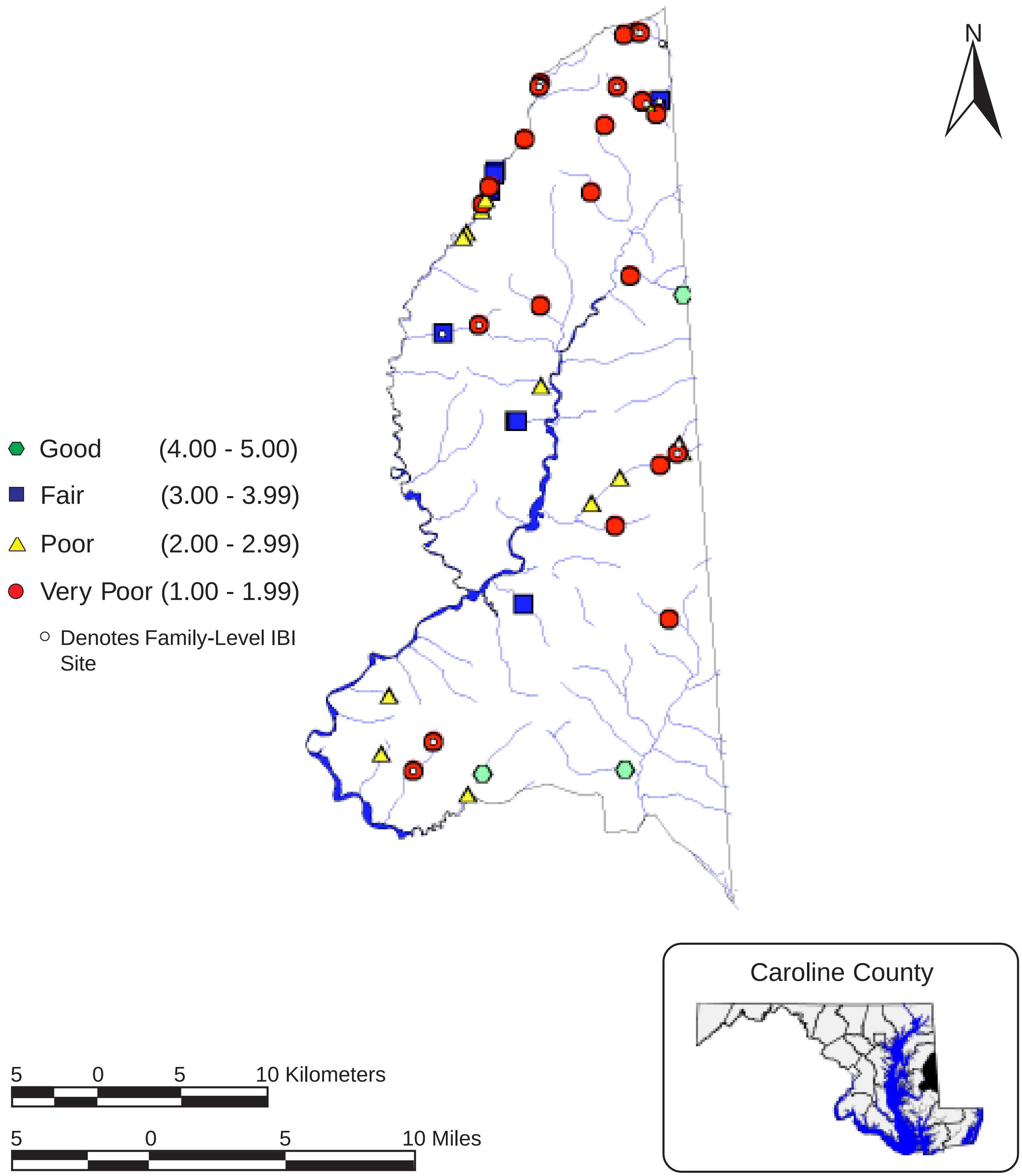

Figure 4. Stream ecological conditions based on the Benthic Macroinvertebrate Index of Biotic Integrity (B-IBI) at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Table 4. Percent occurrence of reptile and amphibian species collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Family	Common Name	Scientific Name	Number of Occurrences	Percent Occurrence
Bufonidae	Fowler's toad	*Bufo woodhousii fowleri*	6	14.63
Ranidae	bullfrog	*Rana catesbeiana*	24	58.54
	green frog	*Rana clamitans melanota*	22	53.66
	pickerel frog	*Rana palaustris*	10	24.39
	southern leopard frog	*Rana utricularia*	10	24.39
	wood frog	*Rana sylvatica*	1	2.44
Chelydridae	common snapping turtle	*Chelydra serpentina*	7	17.07
Kinosternidae	common musk turtle	*Sternotherus odoratus*	4	9.76
Emydidae	eastern painted turtle	*Chrysemys p. picta*	1	2.44
Colubridae	black rat snake	*Elaphe o. obsoleta*	2	4.88
	northern water snake	*Nerodia s. sipedon*	5	12.20
	rough green snake	*Opheodrys aestivus*	1	2.44
None			4	9.76

Table 5. Physical habitat data for Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Site	Instream Habitat[1]	Epifaunal Substrate[1]	Velocity/Depth Diversity[1]	Pool Quality[1]	Riffle Quality[1]	Percent Embeddedness[1]	Percent Shading[1]	Maximum Depth (cm)[1]	Number of Woody Debris	Number of Rootwads	Percent Channel Flow[1]	Channel Alteration[1]	Bank Stability[1]	Riparian Width (m)[1]	Aesthetic Rating[1]
CN-N-002-1-94	6	4	10	9	12	99	85	48	3		90	6	14	50	12
CN-N-002-2-94	11	10	13	16	11	99	60	81	7		90	15	14	50	16
CN-N-004-311-97	16	17	15	14	16	98	70	104	15	5	85	10	13	50	8
CN-N-005-103-97	17	14	16	15	15	60	80	59	5	2	95	10	12	20	15
CN-N-016-107-97	5	3	2	6	6	100	20	18	1	0	40	2	15	4	13
CN-N-020-109-96	15	10	8	10	4	100	65	43	7	6	70	5	16	10	6
CN-N-023-3-94	7	5	2	2	5	99	60	22	5		70	17	18	50	15
CN-N-024-113-96	12	10	4	8	2	85	80	39	7	3	85	9	10	37	17
CN-N-028-1-94	15	10	12	10	8	60	75	89	6		95	5	15	25	13
CN-N-028-2-94	9	6	5	4	8	95	75	23	4		70	9	14	15	16
CN-N-031-122-95	10	5	6	11	0	100	10	50	0	0	10	2	13	15	16
CN-N-034-1-94	15	9	6	4	9	99	85	61	15		95	17	17	25	17
CN-N-034-2-94	13	5	3	3	6	99	60	19			70	17	18	50	17
CN-N-035-1-94	13	5	7	9	6	99	80	37	6		70	18	19	50	18
CN-N-035-2-94	12	5	8	9	7	99	90	47	7		80	18	19	50	18
CN-N-039-108-96	16	6	7	13	5	100	5	49	0	0	75	2	15	4	15
CN-N-039-2-94	9	5	7	10	0	99	15	42	0		10	4	11	5	4
CN-N-039-8-94	10	6	5	3	7	99	95	12	0		50	5	14	50	16
CN-N-041-205-96	18	16	15	16	16	100	65	94	7	6	95	11	15	50	16
CN-N-043-102-97	6	5	5	5	7	90	10	33	0	0	90	5	15	5	13
CN-N-044-1-94	15	7	10	16	11	60	60	64	10		75	12	18	50	17
CN-N-044-3-94	14	12	14	13	13	40	75	64	7		80	15	18	50	16
CN-N-046-105-97	6	5	4	6	6	100	10	34	1	0	50	3	16	5	15
CN-N-049-116-97	17	16	6	18	0	60	65	92	11	12	100	5	18	20	16
CN-N-050-102-96	16	13	14	11	11	50	40	36	0	0	45	7	14	15	16
CN-N-051-202-96	16	15	18	15	16	30	75	98	8	5	90	11	13	50	17
CN-S-002-111-96	15	16	15	16	14	95	70	130	12	6	90	16	17	50	17
CN-S-006-208-95	16	13	12	12	13	50	60	58	7	7	90	13	15	50	14
QA-N-052-202-97	11	7	16	14	16	95	10	88	0	0	100	4	12	0	6
QA-N-085-307-97	12	7	5	8	14	80	20	44	0	0	100	11	16	2	13
QA-N-085-312-97	10	8	5	7	7	95	10	60	0	0	75	8	16	10	16
QA-N-098-301-96	15	14	16	14	15	90	10	93	1	0	95	10	10	25	18
QA-N-098-302-96	16	9	16	15	16	25	15	88	0	0	65	5	14	5	16
QA-N-098-302-97	10	8	11	13	15	70	20	64	0	0	85	6	16	0	10
QA-N-098-307-96	10	13	10	15	12	40	15	103	0	0	90	6	10	50	16

Table 5 (cont.). Physical habitat data for Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Site	Instream Habitat[1]	Epifaunal Substrate[1]	Velocity/Depth Diversity[1]	Pool Quality[1]	Riffle Quality[1]	Percent Embeddedness[1]	Percent Shading[1]	Maximum Depth (cm)[1]	Number of Woody Debris	Number of Rootwads	Percent Flow[1]	Channel Alteration[1]	Bank Stability[1]	Riparian Width (m)[1]	Aesthetic Rating[1]
QA-N-098-308-96	18	15	16	13	17	40	30	72	0	0	90	5	15	14	15
QA-N-098-308-97	13	12	10	11	15	50	20	65	0	0	55	7	15	15	17
QA-N-098-309-96	18	15	15	15	14	35	20	66	0	0	95	5	15	19	11
QA-N-098-315-97	11	12	10	10	14	60	20	49	0	0	80	6	14	14	16
QA-N-105-1-94	10	5	6	15	0	99	20	64	0		70	4	7	3	16
QA-N-105-2-94	10	8	6	10	0	99	20	71	0		50	5	5	2	5

[1] MBSS Qualitative Habitat Metric - See Appendix B for Guidance

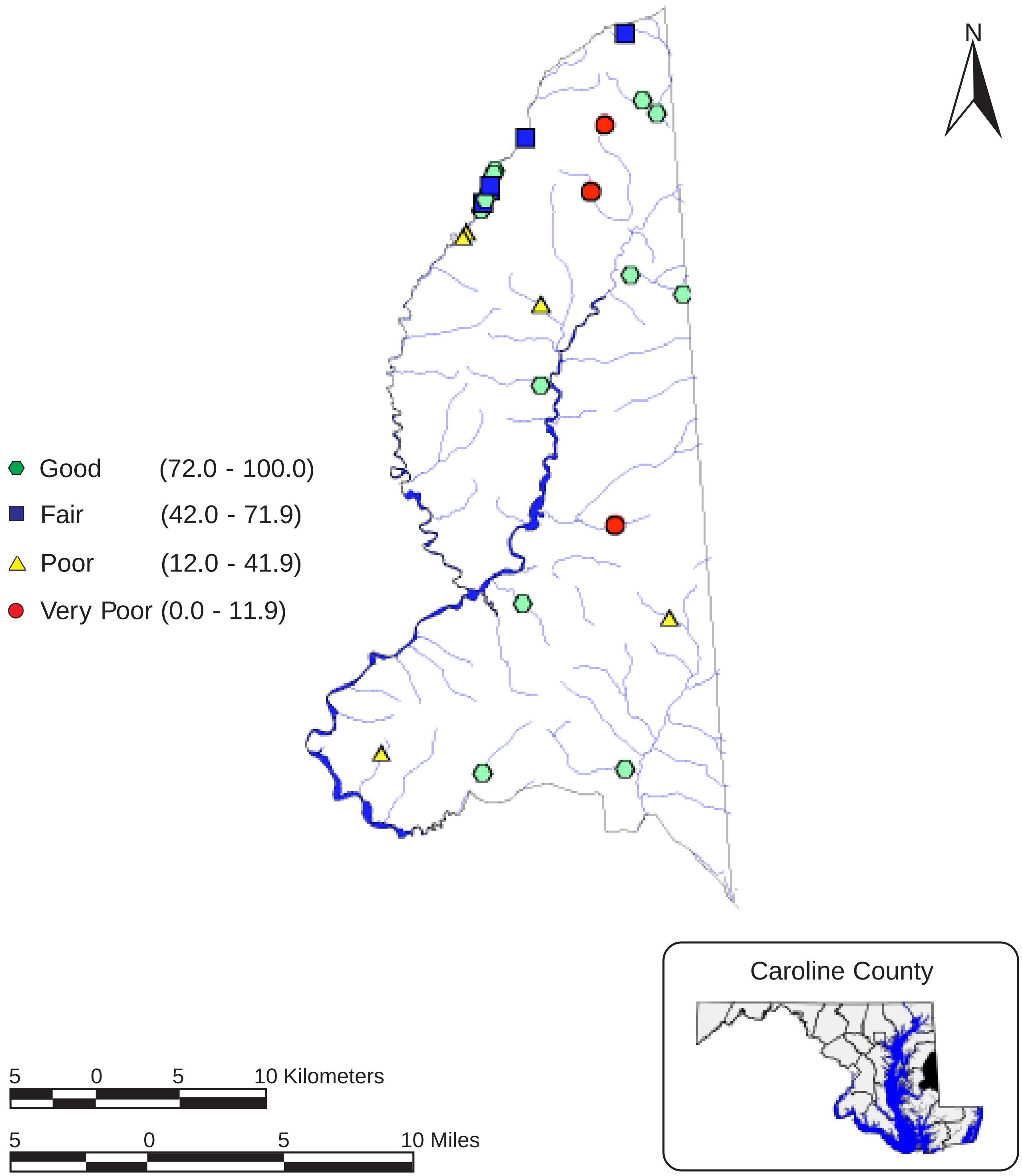

Figure 5. Stream ecological conditions based on the Physical Habitat Index (PHI) at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Table 6. Fish Index of Biotic Integrity (F-IBI), Benthic Macroinvertebrate Index of Biotic Integrity (B-IBI), Family-Level Benthic Macroinvertebrate Index of Biotic Integrity (Fam. IBI), and Physical Habitat Index (PHI) scores at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Site	Stream Name	F-IBI	B-IBI	Fam. IBI	PHI
CN-N-002-1-94	Tidy Island Cr	3.25		3.29	
CN-N-002-2-94	Tidy Island Cr	3.00	3.6		
CN-N-004-311-97	Tidy Island Cr	4.00	1.6		81.68
CN-N-005-103-97	Un Trib To Choptank R	3.00	2.1		89.42
CN-N-007-3-94	Webber Br			2.14	
CN-N-016-107-97	Un Trib To Tidy Island Cr		1.3		6.15
CN-N-020-109-96	Un Trib To Forge Br	3.75	1.9		34.72
CN-N-023-3-94	Burrsville Br	2.00	2.1		
CN-N-023-9-94	Burrsville Br			1.57	
CN-N-024-113-96	Un Str	2.75	2.1		28.99
CN-N-028-1-94	Piney Br	2.50		3.29	
CN-N-028-2-94	Piney Br	2.75		1.57	
CN-N-031-122-95	Tommy Wright Branch	3.75	1.9		33.97
CN-N-034-1-94	Marsh Cr	3.50		1.86	
CN-N-034-2-94	Marsh Cr	2.50		1.57	
CN-N-035-1-94	Choptank R	3.00	3.3		
CN-N-035-2-94	Choptank R	3.25	3.3		
CN-N-039-1-94	Harrington Beaverdam Ditch			1.00	
CN-N-039-108-96	Un Trib To Beaverdam Ditch	3.75	1.3		56.49
CN-N-039-2-94	Harrington Beaverdam Ditch	3.50		1.29	
CN-N-039-8-94	Harrington Beaverdam Ditch				
CN-N-041-205-96	Gravelly Br	3.25	4.1		90.42
CN-N-043-102-97	Un Trib To Herring Run	2.50	1.3		10.73
CN-N-044-1-94	Watts Cr	3.50	2.7		
CN-N-044-207-97	Burrsville Br		1.6		
CN-N-044-3-94	Watts Cr	4.00	2.4		
CN-N-046-105-97	Oldtown Br	2.25	1.3		10.83
CN-N-049-116-97	Robbins Br	3.75	3.3		85.59
CN-N-050-1-94	Coolspring Br			2.43	
CN-N-050-102-96	Coolspring Br	3.50	1.9		78.15
CN-N-050-2-94	Coolspring Br			1.29	
CN-N-051-202-96	Gravelly Br	3.75	1.9		95.75
CN-N-058-120-97	Mitchell Run		2.7		
CN-S-002-111-96	Hunting Cr	3.50	4.1		91.84
CN-S-006-208-95	Ut Marshy Hope Creek	4.00	4.4		78.53
CN-S-010-117-97	Hunting Cr		2.4		
QA-N-052-202-97	Mason Br	4.50	1.9		69.02
QA-N-085-307-97	Mason Br	4.50	2.1		28.99
QA-N-085-312-97	Mason Br	4.50	2.4		25.92
QA-N-098-301-96	Mason Br	4.75	3.0		88.21
QA-N-098-302-96	Mason Br	4.75	3.0		94.18
QA-N-098-302-97	Mason Br	4.50	3.3		56.49
QA-N-098-307-96	Mason Br	4.25	3.3		81.18
QA-N-098-308-96	Mason Br	4.25	2.7		91.59
QA-N-098-308-97	Mason Br	4.75	1.9		70.64
QA-N-098-309-96	Mason Br	4.75	2.4		90.61
QA-N-098-315-97	Mason Br	5.00	1.9		55.13
QA-N-105-1-94	Long Marsh Ditch			1.57	
QA-N-105-2-94	Long Marsh Ditch			1.57	

Table 7. Water chemistry data collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

Site	pH	Conductivity (µS/cm)	Acid Neutralizing Capacity (µeq/L)	Nitrate (mg/L)	Sulfate (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Organic Carbon (mg/L)
CN-N-002-1-94							
CN-N-002-2-94	6.23	0.110	211.65	0.886	21.447		12.00
CN-N-004-311-97	6.68	0.131	355.70	0.828	17.791	6.60	7.30
CN-N-005-103-97	6.70	0.195	188.60	8.901	9.701	9.00	2.10
CN-N-007-3-94	6.33	0.116	223.07	2.999	9.324		10.00
CN-N-016-107-97	5.95	0.111	191.30	1.875	17.260	4.30	6.30
CN-N-020-109-96	6.15	0.117	95.40	4.064	8.418	7.60	6.60
CN-N-023-3-94							
CN-N-023-9-94	6.56	0.106	267.24	1.989	9.514		9.00
CN-N-024-113-96	5.95	0.099	100.30	0.598	15.902	7.30	15.90
CN-N-028-1-94	6.05	0.221	175.69	9.228	9.118		6.00
CN-N-028-2-94							
CN-N-031-122-95	6.52	0.131	212.70	6.103	5.808	9.30	2.00
CN-N-034-1-94	6.84	0.169	323.42	7.859	16.339		6.00
CN-N-034-2-94							
CN-N-035-1-94							
CN-N-035-2-94	6.10	0.098	153.98	3.300	6.247		8.00
CN-N-039-1-94							
CN-N-039-108-96	6.04	0.198	191.50	1.627	17.553	7.70	9.10
CN-N-039-2-94	6.42	0.117	216.96	2.309	23.674		12.00
CN-N-041-205-96	6.38	0.135	34.90	3.760	14.162	9.50	6.90
CN-N-043-102-97	6.86	0.173	247.60	6.669	10.339	11.50	4.20
CN-N-044-1-94	6.43	0.099	164.43	1.901	9.761		8.00
CN-N-044-207-97	6.18	0.061	208.80	0.410	5.244		7.80
CN-N-044-3-94							
CN-N-046-105-97	5.67	0.095	64.10	0.786	15.596	6.30	5.70
CN-N-049-116-97	6.49	0.097	154.80	2.242	9.930	4.00	7.70
CN-N-050-1-94	5.95	0.088	80.80	0.797	20.094		4.00
CN-N-050-102-96	6.31	0.103	167.90	0.880	17.368	9.40	5.60
CN-N-050-2-94							
CN-N-051-202-96	6.60	0.139	165.40	4.395	15.155	9.70	5.80
CN-N-058-120-97	5.72	0.114	90.80	2.520	10.124		16.30
CN-S-002-111-96	6.51	0.189	104.40	8.614	15.691	9.20	4.00
CN-S-006-208-95	6.57	0.191	219.72	10.467	12.853	7.40	3.00
CN-S-010-117-97	6.76	0.193	285.70	8.471	12.913		3.40
QA-N-052-202-97	6.61	0.110	323.00	1.915	15.766	8.50	6.60
QA-N-085-307-97	6.45	0.122	228.70	3.181	12.410	6.60	7.50
QA-N-085-312-97	6.73	0.131	299.30	3.532	12.167	6.30	6.60
QA-N-098-301-96	6.42	0.141	222.10	3.722	17.353	9.60	7.20
QA-N-098-302-96	6.44	0.137	216.70	3.617	17.549	12.20	7.10
QA-N-098-302-97	6.58	0.119	230.00	2.861	13.101	6.30	7.60
QA-N-098-307-96	6.37	0.144	201.50	3.635	16.193	10.20	6.60
QA-N-098-308-96	6.42	0.142	193.70	3.651	17.129	10.00	6.20
QA-N-098-308-97	6.53	0.119	243.30	2.900	12.950	14.00	7.80
QA-N-098-309-96	6.47	0.145	224.80	3.617	17.357	13.80	6.90
QA-N-098-315-97	6.40	0.107	265.40	2.100	11.920	6.10	10.90
QA-N-105-1-94							
QA-N-105-2-94	6.37	0.103	213.98	1.500	18.321		7.00

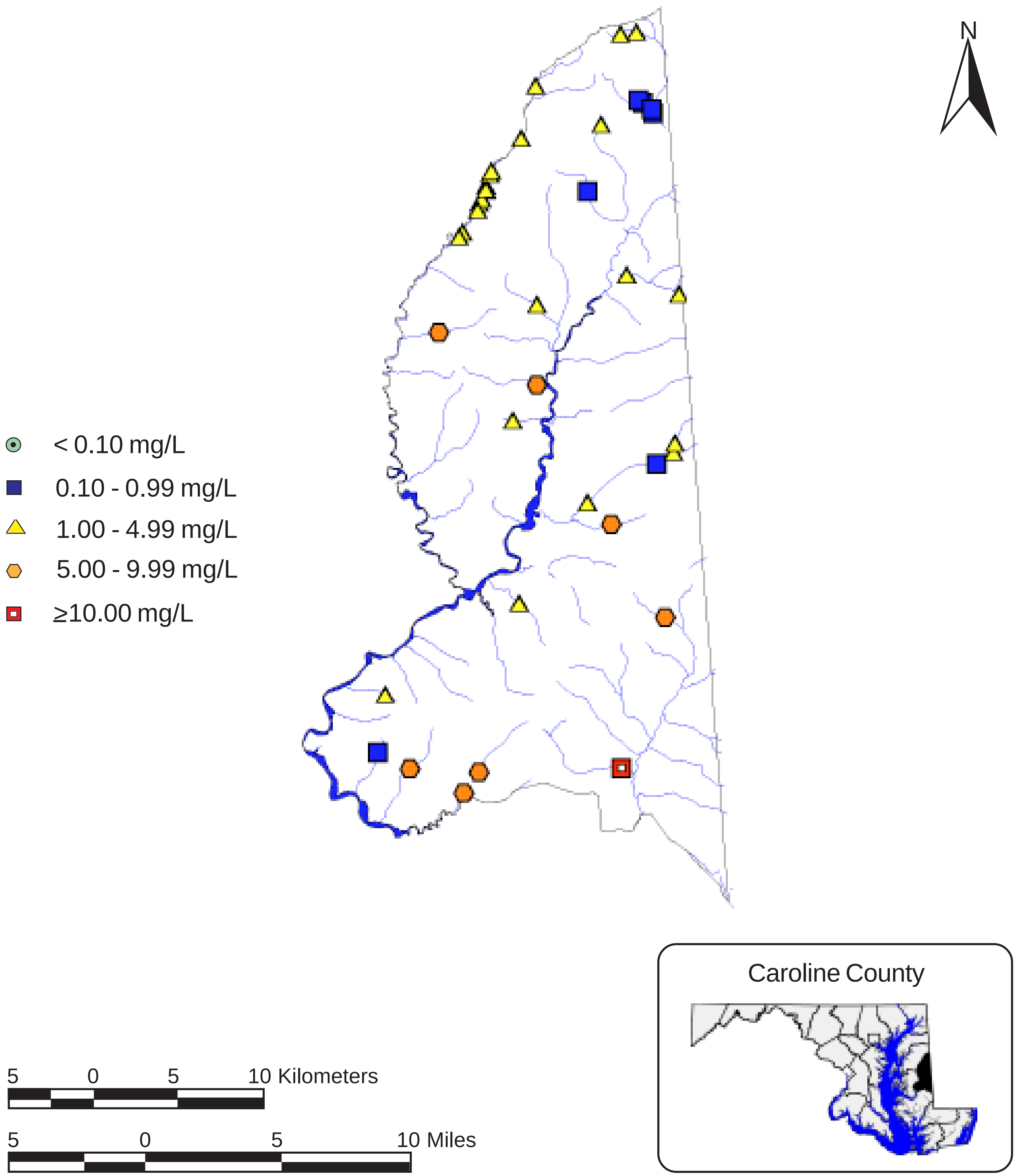

Figure 6. Nitrate-nitrogen concentrations (mg/L) at Maryland Biological Stream Survey sites in Caroline County, 1994-1997.

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Appendix A. Summary of the types of data collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997. Abbreviations used are as follows: F-IBI - Fish Index of Biotic Integrity; B-IBI Benthic Macroinvertebrate Index of Biotic Integrity; Fam.IBI - Family-Level Benthic Macroinvertebrate Index of Biotic Integrity; PHI - Physical Habitat Index.

Site	Stream Name	Fish	Benthic Macroinvertebrate	Herpetofauna	Habitat	Water Chemistry	F-IBI	B-IBI	Fam. IBI	PHI
CN-N-002-1-94	Tidy Island Cr	X	X	X	X		X		X	
CN-N-002-2-94	Tidy Island Cr	X	X	X	X	X	X	X		
CN-N-004-311-97	Tidy Island Cr	X	X	X	X	X	X	X		X
CN-N-005-103-97	Un Trib To Choptank R	X	X	X	X	X	X	X		X
CN-N-007-3-94	Webber Br		X			X			X	
CN-N-016-107-97	Un Trib To Tidy Island Cr	X	X	X	X	X		X		X
CN-N-020-109-96	Un Trib To Forge Br	X	X	X	X	X	X	X		X
CN-N-023-3-94	Burrsville Br	X	X	X	X		X	X		
CN-N-023-9-94	Burrsville Br		X			X			X	
CN-N-024-113-96	Un Str	X	X	X	X	X	X	X		X
CN-N-028-1-94	Piney Br	X	X	X	X	X	X		X	
CN-N-028-2-94	Piney Br	X	X	X	X		X		X	
CN-N-031-122-95	Tommy Wright Branch	X	X	X	X	X	X	X		X
CN-N-034-1-94	Marsh Cr	X	X	X	X	X	X		X	
CN-N-034-2-94	Marsh Cr	X	X	X	X		X		X	
CN-N-035-1-94	Choptank R	X	X	X	X		X	X		
CN-N-035-2-94	Choptank R	X	X	X	X	X	X	X		
CN-N-039-1-94	Harrington Beaverdam Ditch		X						X	
CN-N-039-108-96	Un Trib To Beaverdam Ditch	X	X	X	X	X	X	X		X
CN-N-039-2-94	Harrington Beaverdam Ditch	X	X	X	X	X	X		X	
CN-N-039-8-94	Harrington Beaverdam Ditch	X		X	X					
CN-N-041-205-96	Gravelly Br	X	X	X	X	X	X	X		X
CN-N-043-102-97	Un Trib To Herring Run	X	X	X	X	X	X	X		X
CN-N-044-1-94	Watts Cr	X	X	X	X	X	X	X		
CN-N-044-207-97	Burrsville Br		X			X		X		
CN-N-044-3-94	Watts Cr	X	X	X	X		X	X		
CN-N-046-105-97	Oldtown Br	X	X	X	X	X	X	X		X
CN-N-049-116-97	Robbins Br	X	X	X	X	X	X	X		X
CN-N-050-1-94	Coolspring Br		X			X			X	
CN-N-050-102-96	Coolspring Br	X	X	X	X	X	X	X		X
CN-N-050-2-94	Coolspring Br		X						X	
CN-N-051-202-96	Gravelly Br	X	X	X	X	X	X	X		X
CN-N-058-120-97	Mitchell Run		X			X		X		
CN-S-002-111-96	Hunting Cr	X	X	X	X	X	X	X		X
CN-S-006-208-95	Ut Marshy Hope Creek	X	X	X	X	X	X	X		X

Appendix A (cont.). Summary of the types of data collected at Maryland Biological Stream Survey sites in Caroline County, 1994-1997. Abbreviations used are as follows: F-IBI - Fish Index of Biotic Integrity; B-IBI - Benthic Macroinvertebrate Index of Biotic Integrity; Fam. IBI - Family-Level Benthic Macroinvertebrate Index of Biotic Integrity; PHI - Physical Habitat Index.

Site	Stream Name	Fish	Benthic Macroinvertebrate	Herpetofauna	Habitat	Water Chemistry	F-IBI	B-IBI	Fam. IBI	PHI
CN-S-010-117-97	Hunting Cr		X			X		X		
QA-N-052-202-97	Mason Br	X	X	X	X	X	X	X		X
QA-N-085-307-97	Mason Br	X	X	X	X	X	X	X		X
QA-N-085-312-97	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-301-96	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-302-96	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-302-97	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-307-96	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-308-96	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-308-97	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-309-96	Mason Br	X	X	X	X	X	X	X		X
QA-N-098-315-97	Mason Br	X	X	X	X	X	X	X		X
QA-N-105-1-94	Long Marsh Ditch	X	X	X	X				X	
QA-N-105-2-94	Long Marsh Ditch	X	X	X	X	X			X	

Appendix B. Physical habitat condition measured by the Maryland Biological Stream Survey, 1994-1997. All variables rated on a scale of 0 (poor) to 20 (optimal) unless otherwise noted.

SUBSTRATE AND INSTREAM COVER

Instream Habitat is rated according to the perceived value of habitat to the fish community. Higher scores are assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores are assigned to sites with a high degree of uneven substrate, including logs and rootwads. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

Epifaunal Substrate is rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, flocculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

Velocity/Depth Diversity is rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric varies by stream gradient.

Pool/Glide/Eddy Quality is rated based on the variety and spatial complexity of slow or still water habitat within the sample segment. In high-gradient streams, functionally important slow water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

Riffle/Run Quality is based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

Embeddedness is a percentage of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams, embeddedness may be high even in relatively unimpaired watersheds.

CHANNEL CHARACTER

Channel Alteration is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms that parallel the stream channel.

Bank Stability is rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

Channel Flow Status is the percentage of the stream channel that has water, with subtractions made for exposed substrates and dewatered areas.

RIPARIAN CORRIDOR

Shading is rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by land forms.

Appendix B (cont.). Physical habitat condition measured by the Maryland Biological Stream Survey, 1994-1997. All variables rated on a scale of 0 (poor) to 20 (optimal) unless otherwise noted.

Riparian Buffer is rated according to the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture that have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable, or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the narrowest representative buffer width in the segment (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the stream segment may have a well developed riparian buffer.

AESTHETICS/REMOTENESS

Aesthetics are rated according to the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

Remoteness is rated based on the absence of detectable human activity and difficulty in accessing the segment.